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In re application of:

Schultz

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For: System and Method for Signalling Downhole Conditions to Surface

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INFORMATION DISCLOSURE STATEMENT

APR 07 2003

Honorable Commissioner of Patents and Trademarks

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GROUP 3600

Sir:

The accompanying form PTO- 1449 lists one or more documents which may be considered material to the examination of this application. A copy of each document is provided, if available.

Applicant reserves the right to establish the patentability of the claimed invention over any of the listed documents should they be applied thereagainst as references, and/or to prove that some of these documents may not be prior art, may not be within an analogous field of art, and/or may not be enabling for the teachings they purport to offer.

This statement should not be construed as a representation that an exhaustive search has been made, nor that more material information does not exist.

The Examiner is specifically requested to conduct an independent and thorough review of the documents, and to form his own opinions as to the significance of those documents to patentability of the claimed inventions, regardless of any of the foregoing statements concerning the significance of the references. The foregoing statements are made in good faith, and in compliance with the duty of disclosure; but they cannot substitute for the Examiner's specialized expertise, nor are they intended to derogate from the Examiner's official duty to assess patentability.

It is also respectfully noted that the submission of this material is not intended to displace the Examiner's professional ability and duty to search. Indeed, the Examiner is specifically requested not to rely on the materials submitted herewith, but to conduct a full and independent search.

It is respectfully requested that the Examiner initial and return a copy of the enclosed PTO-1449, to indicate in the file of this patent application that the documents have been considered.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Ngon Pham", with a long horizontal flourish extending to the right.

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# ANALYSIS OF US PATENTS RELATING TO ROCK BIT FAILURE DETECTION

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| #  | US<br>Class | Patent<br>Number | Date of<br>Patent | Title of Patent   | Inventors          | Assignee           | Abstract  |
|----|-------------|------------------|-------------------|---|--------------------|--------------------|---|
|    | 255-61      | 2,560,328        | July 10, 1951     | Dull bit<br>indicator   | W. Bielstein       | Standard<br>Oil    | The flapper closes the<br>duct when the blades of<br>drill bit are worn, and the<br>pressure of the drilling<br>fluid increases             |
| 2  | 255-61      | 2,582,312        | Jan. 15, 1952     | Wear indicati -<br>ng device for<br>drill bits                  | D.L. Del'<br>Homme | Reed               | Drill bit with the wear<br>tube and moving valve<br>member, which opens<br>outlets and drops the<br>drilling fluid pressure                 |
| 3  | 175-39      | 3,011,566        | Dec. 5, 1961      | Bearing wear<br>indication for<br>a roller bit                  | J.W. Graham        | Jersey<br>Product. | The capsule with the<br>tracer material in the<br>bearing of a roller bit   |
| 4  | 175-39      | 3,058,532        | Oct 16, 1962      | Drill bit condi-<br>tion indicator<br>and signaling<br>system   | R.L. Alder         | Dresser            | Electric, electromagnetic,<br>oscillatory or radioactive<br>signal about the wear of<br>the cones   |
| 5. | 175-39      | 3,062,302        | Nov 6, 1962       | Indicator<br>device for<br>bearing<br>failures in drill<br>bits | F.J. Toth et al    | Shell              | A temperature-sensing<br>and heat transmitting<br>system with explosive<br>charge or a fusible plug,<br>which changes the fluid<br>pressure |
| 6  | 175-39      | 3,363,702        | Jan. 16, 1968     | Rock bit dull-<br>ness indicator                                | W. Bielstein       | Esso               | A wear probe engages<br>heel teeth of cones and   |



|    |                   |           |               |   |                    |          |  |
|----|-------------------|-----------|---------------|---|--------------------|----------|--|
|    |                   |           |               |   |                    |          | provides a drop in mud pressure  |
| 7  | 175-39            | 3,578,092 | May 11, 1971  | Drilling tools  | H.J. Tesch et al.  | Farbwerk | A drilling tool has a closed cavity, which contains the gas krypton  |
| 8  | 73-151<br>175-39  | 3,581,564 | June 1, 1971  | Method for detecting roller bit bearing failure                                 | F.S. Young         | Esso     | Rotary torque and drilling rate are measured and its ratio is calculated. A sharp increase of this ratio indicates bearing failure   |
| 9  | 116-114<br>175-39 | 3,678,883 | July 25, 1972 | Worn bearing indicator  | J.F. Fisher        | Smith    | An insert in the bearing of cones jams or locks the dull bearing and there is an increase in torque, or a breakable insert indicates the bearing wear by radio- active or dye material |
| 10 | 73-151<br>175-39  | 3,703,096 | Nov 21, 1972  | Method of determining downhole occurrences in well drilling using rotary torque | A.L. Vitter et al. | Chevron  | Measurement of the rotary torque oscillations for the indicating bit damage  |

|    |                  |           |              |  |                    |                      |   |
|----|------------------|-----------|--------------|--|--------------------|----------------------|---|
|    |                  |           |              | oscillation measurements   |                    |                      |   |
| 11 | 73-104           | 3,714,822 | Feb.6, 1973  | Process for measuring wear on a drilling tool                      | J.Lutz             | Petroles d Aquitaine | A process comprises the registration of vibrations produced by rock bit   |
| 12 | 83-62<br>175-39  | 3,728,919 | Apr24,1973   | Broken tool detector   | W.B.Scott          | Whitney              | Pneumatic circuit opens a passageway for air, the pressure changes and produces an electric signal to indicate breakage of the tool                                       |
| 13 | 73-151<br>175-39 | 3,774,445 | Nov.27, 1973 | Method and apparatus for monitoring the wear on a rotary drill bit | H.A.Rundell et al. | Texaco               | The method includes measuring the revolutions of the drill string and the weight on the bit, as a measure of bit wear   |
| 14 | 73-151<br>175-39 | 3,782,190 | Jan.1,1974   | Method and apparatus for rotary drill testing                      | R.W.Pittman        | Texaco               | Measuring the torque and the weight on the bit, dividing the torque by the weight to indicate incipient roller cone bearing failure when the ratio increases non linearly |
| 15 | 250-303          | 3,818,227 | Jun.18,1974  | Radioactive tracer system to indicate drill bit wear or failure    | B.A.Fries          | Chevron              | Utilizing krypton 85 in clathrate form, in the form of water-soluble kryptonates, or dissolved in grease  |

|    |                   |           |               |  |                   |                  |   |
|----|-------------------|-----------|---------------|--|-------------------|------------------|---|
| 17 | 252-11<br>175-39  | 3,865,736 | Feb 11, 1975  | Radioactive grease containing krypton 85                                   | B.A.Fries         | Chevron          | A radioactive tracer system for indicating drill bit wear utilizing krypton dissolved or dispersed in a grease. It is a variant of the patent #3,818,227                              |
| 18 | 175-39            | 3,913,686 | Oct 21, 1975  | Method and apparatus for preventing and detecting rotary drill bit failure | C.D.Manson        | Halliburton.     | For the drilling of cement inside the casing a drillable core is placed below bottom cementing plug for engaging the roller cutters and excepting its jamming                         |
| 19 | 175-39            | 4,030,558 | Jun. 21, 1977 | Wear determination of drilling bits  | H.R.Morris        | -                | The method comprises the attraction by the magnet the ferrous cutting from the bit in flowing drilling fluid, examining them under a microscope for appreciation of drilling bit wear |
| 20 | 175-107<br>175-39 | 4,114,704 | Sep 19, 1978  | Down hole well drilling  | W.G.Maurer et al. | Maurer Engineer. | A turbo drill with fluid lubricant surrounding the  |

|    |                  |           |               |   |                  |                 |  |
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|    |                  |           |               | tool with reversible thrust bearings              |                  |                 | bearings and indication of loss of lubricant or wear of thrust bearings by change the mud pressure   |
| 21 | 73-151<br>175-39 | 4,346,591 | Aug. 31, 1982 | Sensing impending sealed bearing and gage failure | R.F. Evans       | -               | Use of electrical conduction elements for sense the presence of the aqueous fluid inside of bearing. A signal is transmitted to the surface by mud pulse telemetry   |
| 22 | 175-39           | 4,436,164 | Mar 13, 1984  | Lubrication failure detection system              | L.L. Garner      | Globe Oil Tools | Drill bit has a lubrication reservoir with flexible membrane that contacts a piston when the lubricant is depleted, and the pressure of the drilling fluid decreases |
| 23 | 29-434           | 4,441,244 | Apr 10, 1984  | Sealed bearing rotary rock bit assembly           | G.A. Cason       | Dresser         | Detecting water in the bearings and lubricant reservoir system of rock bit while manufacturing of one  |
| 24 | 175-40           | 4,548,280 | Oct 22, 1985  | Drill bit having a failure indicator              | J.E. Daly et al. | Reed            | If the lubricant system loses a grease, the piston or the spherical valve decreases or increases the pressure of the drilling fluid                                  |

|    |                  |           |              |  |                      |               |   |
|----|------------------|-----------|--------------|--|----------------------|---------------|---|
| 25 | 367-82<br>175-40 | 4,562,559 | Dec 31, 1985 | Borehole<br>acoustic tele-<br>metry system<br>with phase<br>shifted signal | H.E. Sharp et<br>al. | Sperry<br>Sun | An acoustic signal is<br>placed on the pipe string<br>and transmits the data<br>from the bottom with a<br>minimum level of<br>attenuation |
| 26 | 175-40           | 4,610,313 | Sep. 9, 1986 | Drill bit<br>having a<br>failure<br>indicator                              | J.E. Daly et<br>al.  | Reed          | It is a variant of the patent<br># 4,548,280  |

|    |                  |           |                  |   |              |                   |   |
|----|------------------|-----------|------------------|---|--------------|-------------------|---|
| 29 | 73-151<br>175-39 | 4,685,329 | Aug. 11,<br>1987 | Assessment of<br>drilling<br>conditions | T.M. Burgess | Schlum-<br>berger | A method of assessing<br>drilling conditions and<br>the bit teeth wear includes<br>gathering measurements |
|----|------------------|-----------|------------------|---|--------------|-------------------|---|



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|  |  |  |  |  |  | of torque, WOB, ROP, RPM and its graphical representation |
|--|--|--|--|--|--|---|

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|----|------------------|-----------|---------------|--|------------------|---------------------|---|
| 31 | 175-39           | 4,730,681 | Mar15,1988    | Rock bit cone lock and method                                    | R.D.Estes        | Rock Bit Industries | There is the lockup groove in the ball race of the journal pin for locking the cone after the bushing wear and for increasing the rotary table torque                         |
| 32 | 73-151<br>175-39 | 4,773,263 | Sep27,1988    | Method of analyzing vibrations from a drilling bit in a borehole | M.Lesage et al.  | Schlumberger        | Using of vibrations for the information about the wear of drilling bit. For example, abrupt changes in frequency distribution curves indicate the broken teeth or stuck cones |
| 33 | 175-39           | 4,785,894 | Nov. 22, 1988 | Apparatus for detecting drill                                    | A.P.Davis et al. | Exxon               | The bit wear indicator includes a sensor to detect  |

|    |                   |           |                |  |                      |          |   |
|----|-------------------|-----------|----------------|--|----------------------|----------|---|
|    |                   |           |                | bit wear   |                      |          | the bearing or gauge wear, a tensioned wire extending between the wear sensor and the flow resistance altering valve that increases the pressure of the drilling fluid  |
| 34 | 175-39            | 4,785,895 | Nov.22<br>1988 | Drill bit with wear indicating feature                                       | A.P.Davis et al.     | Exxon    | It is a variant of the patent # 4,785,894   |
| 35 | 407-113<br>175-39 | 4,818,153 | Apr.4,1989     | Cutting insert having means for detecting wear                               | I.H.Strandell et al. | Santrade | Cutting insert has a sub-stratum comprising a photon-emitting material, and the intensity of the photons shows the wear   |
| 36 | 73-151<br>175-39  | 4,852,399 | Aug.1,1989     | Method for determining drilling conditions while drilling                    | I.G.Falconer         | Anadrill | Utilizing surface and sub-surface sensors with an acoustic data transmission system to determine ROP and torque for separate the bit wear from changes in rock strength |
| 37 | 73-151<br>175-39  | 4,876,886 | Oct31,1989     | Method for detecting drilling events from measurement while drilling sensors | M.Bible et al        | Anadrill | It is a variant of the patent # 4,852,399   |

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|----|------------------|-----------|-----------------|--|--------------|-------------------|--|
| 39 | 73-151<br>175-39 | 4, 926686 | May 22,<br>1990 | Method for<br>determining<br>the wear of the<br>cutting means<br>of a tool dur-<br>ing drilling ro-<br>cky formation | H.Fay        | IFP               | Method includes a measu-<br>rement of the WOB and<br>the torque, then the<br>degree of the cutting wear<br>is calculated according to<br>an equation |
| 40 | 175-39           | 4,926,950 | May 22,<br>1990 | Method for<br>monitoring the<br>wear of a<br>rotary type<br>drill bit  | D.H.Zijsling | Shell             | Cutting elements of PDC<br>bit with varying thickness<br>of the front layer  |
| 41 | 73-151<br>175-39 | 4,928,521 | May 29,<br>1990 | Method for<br>determining<br>drill bit wear  | S.Jardine    | Schlum-<br>berger | Method by which the drill<br>bit vibrations and the rate<br>of cones rotation are<br>detected for deriving the<br>state of the drill bit wear        |

|    |                  |           |             | control by vibration analysis   |                   |                          | its failure   |
|----|------------------|-----------|-------------|---|-------------------|--------------------------|---|
| 43 | 175-228          | 5,183,123 | Feb.2, 1993 | Indicating means for a rock bit lubricating system  | K.M. White        | Western Rock Bit Company | A lubricant reservoir of the rock bit has a valve controlling the fluid flow along the passage means intersecting the lubricant reservoir and changing the fluid pressure if the grease depletes  |
| 44 | 73-151<br>175-39 | 5,216,917 | Jun.8, 1993 | Method of determining the drilling conditions associated with the drilling of a formation with a drag bit | E.Detournay       | Schlumberger             | Method comprises measuring WOB, bit torque, angular rotation speed of the bit, ROP and calculating specific energy and drilling strength for the detection of lithology and wear of the bit   |
| 45 | 175-39           | 5,305,836 | Apr26, 1994 | System and method for controlling drill bit usage and well plan   | P.Holbrook et al. | Baroid                   | A method comprises the drilling a portion of well, measuring drilling data, converting these data into electrical signals, inputting its to a computer and continuing use of the bit or retiring the bit in accord with wear calculation signal |

|    |                  |           |               |   |                  |         |  |
|----|------------------|-----------|---------------|---|------------------|---------|--|
| 46 | 175-1<br>175-40  | 5,372,207 | Dec13, 1994   | Seismic prospecting method and device using a drill bit working in a well | C.Naville et al. | IFP     | A method consists in the control of seismic signals from a drill bit in order to characterize the rock crossed and to diagnose the time when the drill bit is worn                             |
| 47 | 73-151<br>175-39 | 5,415,030 | May 16, 1995  | Method for evaluating formations and bit conditions                       | P.N.Jogi et al.  | Hughes  | A method comprises the measurement WOB, bit torque, RPM, ROP and evaluating by calculations the formations and bit condition while drilling  |
| 48 | 175-40<br>175-39 | 5,794,720 | Aug. 18, 1998 | Method of assaying downhole occurrences and conditions                    | L.M.Smith et al. | Dresser | A method comprises the drilling an interval, generating a plurality of electrical incremental actual force and distance signals producing a total work done by the bit and rating the bit wear |

# US PATENTS RELATING TO BEARING FAILURE INDICATORS IN VARIOUS DOMAINS OF INDUSTRY

| # | US Class | Patent Number | Date of Patent | Title of Patent  | Inventors          | Assignee                          | Abstract   |
|---|----------|---------------|----------------|--|--------------------|-----------------------------------|--|
| 1 | 116-114  | 3,853,087     | Dec. 10, 1974  | Bearing failure indicator  | D.B.Aldag          | Panhandle Eastern Pipe Line Co.   | It is an indicator of the failure of the bearings supporting a rotation shaft. A magnet is positioned adjacent a shaft and supported for movement in the direction the shaft moves when the bearings fail. A switch is actuated by such movement to indicate that the bearing has failed |
| 2 | 308-1A   | 4,063,786     | Dec. 20, 1977  | Self-lubricating auxiliary bearing with a main bearing failure indicator | M.E.Rall           | Westinghouse Electric Corporation | An auxiliary bearing structure having a self-lubricating sleeve which is engaged by a shaft mounted runner which also actuates a main bearing failure indicator  |
| 3 | 73-344   | 4,074,575     | Feb. 21, 1978  | Temperature and failure indicating probe for a bearing                   | M.O.Bergman et al. | The Trane Co.                     | A thermistor is disposed within a tubular, electrically conductive, enclosure which one is surrounded by an electrically insulating sleeve for mounting within a bearing. A resistance sensor detects an excess temperature or bearing wear  |
| 4 | 116-67R  | 4,148,271     | Apr. 10, 1979  | Incipient bearing failure indicator                                      | P.M.Majernik       | General Motors                    | If the cage of the bearing fails, the rollers bunch up forming a gap which allows the probe to drop into the gap to unlatch the hammer which swings against the bell to cause a signal of an audible indication of imminent bearing failure  |

|   |         |           |               |  |                    |                                   |  |
|---|---------|-----------|---------------|--|--------------------|-----------------------------------|--|
| 5 | 340-682 | 4,379,291 | Apr.5, 1983   | Bearing failure indicator for rotating electric machines | L.E.Hubbard et al. | Texas Eastern Scientific Research | In an electrical machine, conductive strips insulated from the stator are circularly spaced into the rotor-stator clearance space. Upon excessive lateral rotor movement, it contacts a strip and de-energizes the motor   |
| 6 | 308-227 | 4,425,010 | Jan. 10, 1984 | Fail safe dynamo -electric machine bearing               | R.A.Bryant et al.  | Reliance Electric Co.             | A vertical shaft machine has two bearings at one end of the machine. If the first bearing should fail, then the shaft will drop slightly, due to gravity and applied external forces, and the second bearing will become enabled, rotatably journaling the shaft |
| 7 | 364-507 | 4,493,042 | Jan. 8, 1985  | Bearing failure judging apparatus                        | I.Shima et al.     | Mitsubishi                        | A detected signal wave detected from a bearing is lead to a time domain extracting means and a frequency domain extracting means in order to extract features of the detected signal wave in the time domain and features thereof in the frequency domain        |
| 8 | 246-169 | 4,659,043 | Apr.21, 1987  | Railroad hot box detector                                | C.A.Gallagher      | Servo Corporation of America      | A hot box detector system utilizes an infra-red scanner to scan the bearings of railroad cars passing along a section of track with means for determining if the surfaces being scanned dissipate heat from bearing to bearing                                   |
| 9 | 340-683 | 4,665,393 | May12, 1987   | Vibration monitoring system and apparatus                | P.L.Wilder et al.  | -                                 | The probe assembly is supported on the fixed housing of the rotating shaft for contact therewith upon occurrence   |

|    |          |           |              |   |                    |                              |  |
|----|----------|-----------|--------------|---|--------------------|------------------------------|--|
|    |          |           |              |   |                    |                              | of excessive vibration. An electronic circuit is provided which detects and registers the excessive vibration on the monitor through a visual and audible alarm  |
| 10 | 73-660   | 4,790,190 | Dec.13, 1988 | On-line acoustic detection of bearing defects                   | J.E.Bambara et al. | Servo Corporation of America | It is an apparatus for the detection of acoustic impact frequencies, characteristic of bearing assembly failure during operation, which modulate an acoustic carrier frequency band  |
| 11 | 340-682  | 4,812,826 | Mar.14, 1989 | Thermal sensor for detection of railroad bearing failures       | W.M.Kaufman et al. | Carnegie-Mellon University   | A thermal sensor composed of a standard bolt which has been modified to embody a temperature sensing element and placed into a bearing assembly of a train. This element contains a heat-sensitive wax that at a preset temperature expands causing the motion of a piston which exposes projections |
| 12 | 73-651   | 5,001,993 | Mar.26, 1991 | Micromechanical vibration sensor                                | J.H.Brand          | Secretary of the Army        | The miniature bearing failure sensor includes a micromachined mechanical resonator with a conductive cantilevered beam mounted on a conventional insulating substrate to form a microchip  |
| 13 | 73-118.1 | 5,072,611 | Dec.17, 1991 | Apparatus and method for testing wheels, bearing and lubricants | J.M.Budd et al.    | The B.F. Goodrich Co.        | A test apparatus comprises a hub and wheel web rotatably mounted on a bearing set in the wheel hub and mounted on a non-rotatable axle mechanism. An acoustic sensing means enable determination of the onset of bearing failure   |



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|----|---------|-----------|---------------|---|--------------------|---------------------------------|--|
| 14 | 340-682 | 5,140,311 | Aug. 18, 1992 | Pump shut-down system                             | F. Cooc            | Chevron                         | A pump shut-down system prevents damage to the pump from bearing failure and has a metal bar, voltage source and automatic shut-down relay   |
| 15 | 384-551 | 5,249,871 | Oct. 5, 1993  | High force ball bearing                           | R.R. LaTorte       | Raytheon Co.                    | A ball bearing assembly with a spacer to prevent bearing failures. The spacer has two rings which are coupled to the outer and inner rings of the bearing. The spacer allows relative rotation of the ball bearing rings but prevents relative translation of the rings beyond a point which will damage the bearing |
| 16 | 310-90  | 5,602,437 | Feb. 11, 1997 | Bearing failure detector for electric generator   | M. Shahamat et al. | Lucas Aerospace Power Equipment | A bearing failure detector includes a disk which is connected to a resistor which is monitored by a control circuit. When the clearance of the bearings enlarges by predetermined amount, the resistance changes to provide an indication that the bearing need replacement  |
| 17 | 350-584 | 5,633,628 | May 27, 1997  | Wheelset monitoring system                        | J.M. Denny         | General Railway Signal          | A temperature sensor extends into the wheel assembly in order to obtain accurate readings of high temperatures. Upon determination of a warning condition, an electronic circuit transmits a warning signal to a wayside station or train crew   |
| 18 | 73-593  | 5,677,488 | Oct. 14, 1997 | Piezoelectric film transducer system for bearings | R. Monahan         | NTN                             | A bearing monitoring system uses a piezoelectric film transducer for detecting and predicting bearing failure  |

|    |         |           |               |  |                  |                            |   |
|----|---------|-----------|---------------|--|------------------|----------------------------|---|
| 19 | 340-682 | 5,691,707 | Nov. 25, 1997 | Sensory fitting for monitoring bearing performance | C.C.Smith et al. | Security Operating Systems | A device for monitoring bearing performance in apparatus having an aperture sized and configured to receive the grease fitting. The device includes the temperature or vibration sensing components, or both, to enable detection of impending bearing failure                                    |
| 20 | 384-448 | 5,865,543 | Feb. 2, 1999  | Bearing failure detection apparatus                | J.K.MacLean      | -                          | A warning device is mounted on the stationary axle inside the wheel housing adjacent the brake mounting assembly to remain stationary. The device includes a probe which protrudes outwardly so as to have a sensing end extend until it is a predetermined distance from the rotating brake drum |

# US PATENTS RELATING TO THE DRILL STRING VIBRATIONS

| # | US Class | Patent Number | Date of Patent | Title of Patent | Inventors | Assignee | Abstract |
|---|----------|---------------|----------------|-----------------|-----------|----------|----------|
|---|----------|---------------|----------------|-----------------|-----------|----------|----------|

|   |                  |           |              |  |                     |                                 |  |
|---|------------------|-----------|--------------|--|---------------------|---------------------------------|--|
| 2 | 340-18<br>175-40 | 4,001,773 | Jan. 4, 1977 | Acoustic telemetry system for oil wells utilizing self generated noise | A. E. Lamel et al.  | American Petrosence Corporation | It is a variant of the patent #3,906,434   |
| 3 | 340-18<br>175-40 | 4,040,003 | Aug. 2, 1977 | Downhole seismic source  | P. A. Beynet et al. | Standard Oil                    | A downhole seismic source is used for the determination of the location of the bottom of a bore hole |

|   |                   |           |               |   |                    |                     |   |
|---|-------------------|-----------|---------------|---|--------------------|---------------------|---|
| 5 | 367-81            | 4,903,245 | Feb. 20, 1990 | Downhole vibration monitoring of a drill string | D. A. Close et al. | Exploration Logging | An apparatus for monitoring vibration of a bottom hole assembly includes an accelerometer mounted in the BHA to generate data in the form of electrical signals, which can be taken to prevent damage to downhole equipment |
| 6 | 324-162<br>175-40 | 4,958,125 | Sep. 18, 1990 | Method and apparatus for detecting              | S. Jardine et al.  | Anadrill            | The centripetal acceleration of the drill string is measured at two opposite ends of a  |

|  |  |  |   |  |  |  |
|--|--|--|---|--|--|--|
|  |  |  | etermining characteristics of the movement of a rotating drill string including rotation speed and lateral shocks |  |  | drill string diameter so as to obtain two signals; these signals are combined and the instantaneous rotation speed or the lateral shocks are derived |
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|----|------------------|-----------|--------------|--|----------------|--------|---|
| 8  | 367-25           | 5,159,577 | Oct.27,1992  | Technique for reducing whirling of a drill string  | J.R.Twist      | Baroid | A sensor signals are generated at time intervals of less than half the period of rotation of the drill collar, and the frequency component attributable to the eccentric rotation of the drill collar is determined |
| 9  | 73-151<br>175-40 | 5,226,332 | Jul.13, 1993 | Vibration monitoring system for drillstring  | M. Wassell     | Hughes | A system includes four spaced accelerometers which measure and differentiate between lateral, longitudinal and torsional drillstring vibrations   |
| 10 | 73-151           | 5,321,981 | Jun.21,1994  | Method for analysis of drill string vibration using torsionally induced frequency modulation | J.D.Macpherson | Hughes | Torsional oscillations of the drillstring will lead to frequency modulation of the signal from a vibratory source as the bit and are used to optimize drilling and drillstring performance                          |